STATUS OF INDUS-1 SYNCHROTRON RADIATION SOURCE

A. D. Ghodke, D. Angal-Kalinin, A. Banerjee, D. D. Bhawalkar, A. A. Fakhri, P. Fatnani, P. R. Hannurkar, Pradeep Kant, M. G. Karmarkar, S. Kotaiah, Pradeep Kumar, S. P. Mhaskar, S. S. Prabhu, M. Pravinkumar, A. S. Raja Rao, G. K. Sahoo, S. K. Shukla, B. Singh, G. Singh[§], H.C. Soni and D. K. Vats

Centre for Advanced Technology, Indore - 452 013, India

Abstract

Indus-1 is a 450 MeV electron storage ring for the production of the synchrotron radiation in VUV range with the critical wavelength of 61Å. This storage ring was successfully commissioned in 1999 and since then it has been routinely operated. A maximum beam current of 200mA was accumulated in the ring. Extensive studies of beam lifetime have been carried out. The lifetime of ~ 45 minutes has been increased to ~75 minutes with the application of DC voltage on the ion clearing electrodes. Mainly the vacuum limits the lifetime at present. The beam dynamics studies carried out during different machine runs for beam lifetime, operating point, ion trapping, proposed plans for the augmentation of the machine performance are briefly discussed in this paper.

1 INTRODUCTION

The Indus-1 synchrotron radiation (SR) facility consists of a 450 MeV storage ring named as Indus-1 for the production of VUV radiation [1] and its injector system, which has a 20 MeV microtron and a synchrotron capable of increasing beam energy up to 700 MeV. The synchrotron, transfer lines and the microtron have already been commissioned [2]. The Indus-1 storage ring was commissioned in 1999 [3]. Two bunches out of the three extracted bunches from the synchrotron are injected into the storage ring using a single fast kicker. The parameters of the injection septum, kicker, dipole, quadrupoles are optimised and a stored current of 200 mA was achieved in March 2001. The beam lifetime at the design current of 100 mA is presently limited due to the gas pressure. Results of beam lifetime measurements with and without ion clearing electrodes are discussed.

2 DESCRIPTION OF THE FACILITY

The layout of the Indus-1 SR facility is shown in Fig.1. Pre-injector is a Classical microtron (20 MeV, 20 mA & 1 μs pulse width and rep rate 1 Hz). TL-1 is a beam transport line from microtron up to the synchrotron. Beam acceleration is taking place in synchrotron where energy of the electrons is increased from 20 MeV to 450 MeV in 200 ms. TL-2. Beam transport line from synchrotron up to storage ring Indus-1.

[§]Corresponding Author, Email: gurnam@cat.ernet.in

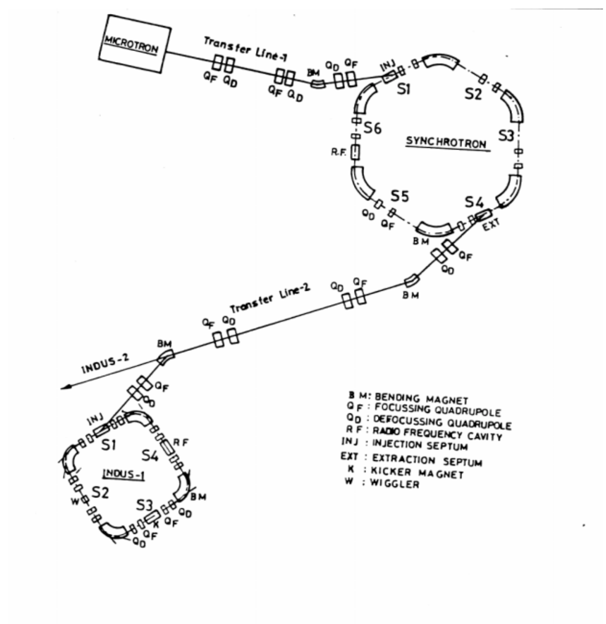


Figure.1: Layout of the Indus-1 SR facility

Fig. 2 shows the extracted two bunches at the end of TL-2 along with the extraction kicker pulse (bottom curve and the pulse comb represents the stored beam bunches in storage ring Indus-1.

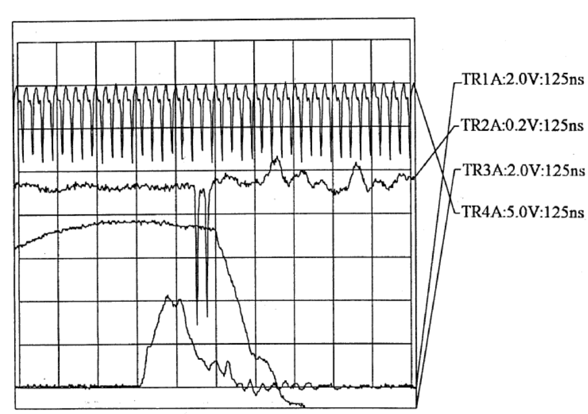
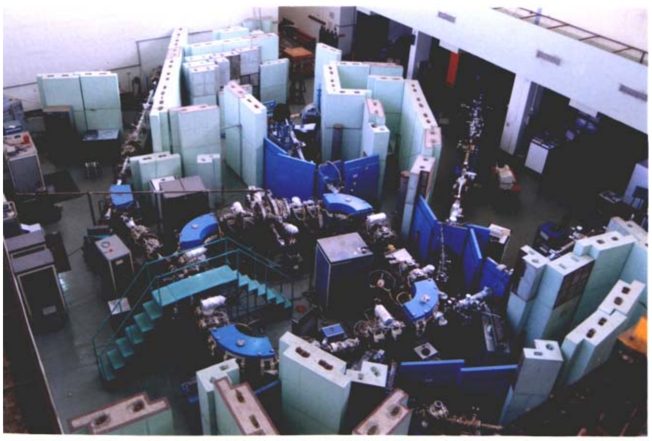


Figure 2: Current signals in TL-2 and Indus-1

3 STORAGE RING INDUS-1

Indus-1 is a 450 MeV electron storage ring designed to satisfy the user requirements in the wavelength range >30 Å. The critical wavelength of radiation is 61 Å. It is a small ring having a circumference of 18.96m. The magnetic lattice of the ring has four superperiods, each consisting of a dipole magnet with a field index of 0.5 and two pairs of the quadrupoles. Each superperiod has a 1.3 m long straight section. The injection septum, the injection kicker and the RF cavity are installed in S1, S3 and S4 respectively. There is a provision to install a 3T wiggler in S2, which will provide the harder synchrotron radiation with critical wavelength of 31Å. To correct the natural chromaticity, a pair of sextupoles is used in each superperiod. The dynamic aperture in the presence of sextupole is larger than vacuum chamber aperture. The ring has a wide tuning range. Parameters of Indus-1 are given in Table 1.



The photograph of the Indus-1 storage ring

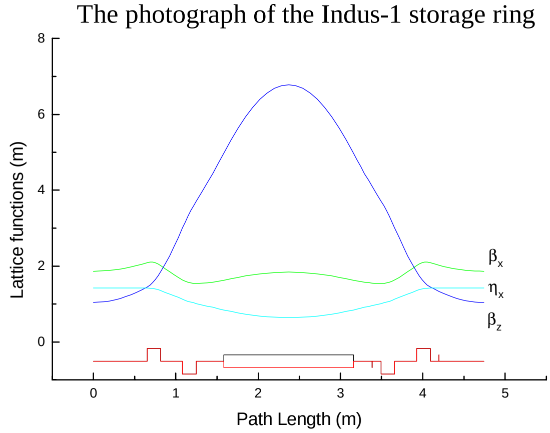


Figure 3: Lattice functions of Indus-1 at (1.69,1.31)

Table-1: Parameters of Indus-1

Energy	450 MeV
Current	100 mA (achieved 200 mA)
Bending Field	1.5 T
Circumference	18.96 m
Operating point	1.69, 1.31
Beam emittance (ε_x)	1.5×10^{-7} m.rad
(ε_z)	1.5×10^{-8} m.rad
Beam size σ_x	0.28 mm
σ_z	0.07 mm (center of BM)
Energy spread	3.85×10^{-4}
Momentum compaction	0.235
Chromaticities ($\xi_{x,z}$)	-1.9,-0.3 (measured -2.6,+3.1)
Revolution frequency	15.82 MHz
Harmonic number	2
Power loss	0.36 kW[a]; 0.05kW[b]

[a] Bending magnet; [b] high field wiggler (3T)

4 BEAM LIFETIME

Elastic and inelastic beam-gas scattering as well as Touschek effect mainly limit electron beam lifetime in the storage ring.

Touschek effect: Electrons are lost due to inelastic coulomb scattering among the electrons within the bunch. It is inversely proportional to the number of electrons in a bunch and more if the bunch volume and energy acceptance is more.

Beam-gas scattering: Beam lifetime can be limited by different beam gas elastic and inelastic scattering process of the beam electrons with the residual gas nuclei as well as electrons. It depends on energy of the beam, transverse and energy aperture of the machine. It is inversely proportional to the gas pressure inside the vacuum envelope. Total beam lifetime is given as:

$$1/\tau = 1/\tau_{Tous} + 1/\tau_{bg}$$

In case of electron storage ring like Indus-1, the vacuum pressure P is not simply constant but depends strongly on the beam current I due beam gas desorption induced by synchrotron radiation heating the vacuum chamber .The measured accumulated dose from 17th Oct 2000 is 21.1 A-hour. The experiments indicate that sometimes the beam has a sharp fall in lifetime and has the following features. It doesn't appear at fixed current, but usually below 15 mA. No correlation between the lifetime drop & Rf voltage and other machine parameters are observed, while adjusting the quadrupoles or turning on the injection kicker may helps some times. To overcome this problem we performed the experiment with ion clearing electrodes, which clears the ions that are trapped inside the vacuum chamber.

4.1 Ion trapping

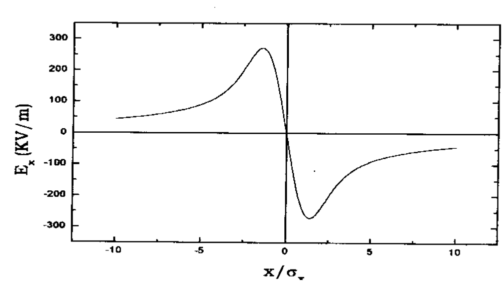


Figure 4: Electric field of a bunch seen by a positive ion.

Electron bunches move in the vacuum chamber of the storage ring may ionise the molecules of the residual gas thus the ions are generated. The motion of these ions could be stable under potential well (Fig.4) of electron bunch if the masses of these ions are more than critical mass, then are trapped. If the density of trapped ions is large enough the motion of the electron beam will be perturbed and as immediate effect, the lifetime of the beam is reduced due to rise in local vacuum pressure. Tracking studies were made using computer code MOTION for Indus-1 Lattice, these studies revels that critical mass varies up to 36 under different filling, tuning and coupling constrains. With DC voltage of 1 kV & RF frequency span 0.8-3.5 MHz at 100 V on ion clearing electrodes are enough for clearing all the ions. At present only 20% circumference is occupied with ion clearing electrodes. The effect of ion clearing on the electron beam lifetime is clearly seen from Figure 5. Beam lifetime improvement from 45 minutes up to 75 minutes is observed.

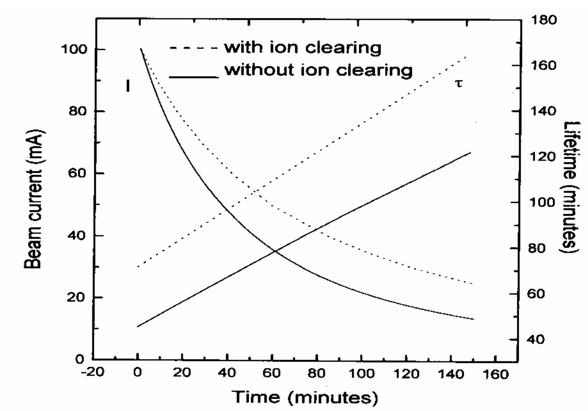


Figure 5: Effect of ion clearing on the beam lifetime

5 ELECTRON BEAM STABILITY

Beam stability has been measured using XUV photodiode (IRD) with Ti filter (UHV) [4], to determine stability, vertical peak position was observed for several days, over several injections and different beam current level. The electron beam orbit is stable with in ± 25μm over a period of 10 days. Stability for same injection is ±12μm.

6 RADIATION LEVELS

Ionising radiation produced due to interaction of electron beam with SS vacuum chamber and residual gas molecules present in it. The main prompt radiation which are of ionising nature are bremsstrahlung x-rays and photo-neutrons. The acceptable radiation dose in our country is 0.1 mR/Hr, Dose rate measured near Indus-1 storage ring with 110mA stored beam current is shown in Table 2. Radiation level outside the shielding around the storage ring during the storage is well within the permissible limits.

Table 2.Radiation dose at 110 mA stored current

Location	Source of radiation	Dose mR/Hr
Main control room	Bremsstrahlung	0.01
Experimental station	Bremsstrahlung	0.02

Neutron flux is negligible

The present status of the beamlines which are installed on the storage ring Indus-1 are shown in Table 3

Table 3: Beamline status

Beam line	Commissioned
PES (I)	Nov 2000
CAT TGM	Dec 2000
PES(II)	June 2001
Photo physics	Under commissioning

7 CONCLUSIONS

The commissioning results obtained up to date dictates that there is no basic limitation in injection and accumulation of the beam. Injection and accumulation are also possible near the theoretical tune point. Although beam lifetime at high accumulated beam current is still small, but the present beam lifetime allowed already the startup of the commissioning of some of the beam lines. Present limitation of the lifetime in Indus-1 is due to beam-gas scattering. It will improve with the improvement in vacuum condition through synchrotron radiation cleaning of the vacuum chamber and on adding ion-clearing electrodes inside all bending magnet chambers of Indus-1.

8 ACKNOWLEDGMENTS

The design, commissioning and operation of Indus-1 facility is a teamwork of many engineers, scientists and technical personnels of Accelerator Programme. We would like to thank all our colleagues for their contribution. We would like to mention the valuable contributions made by Sh. K.K. Thakkar on radiation monitoring.

REFERENCES

[1] G Singh, G.K. Sahoo, B. Singh, Deepa Angal et al, Proceedings of Conference on synchrotron radiation applications, Hefei, China, 1989, pp 122-127.

[2] D Angal, A. Banerjee, AV Filipchenko, A.D. Ghodke et al, Proceedings of 4th International Conference on SRS's and 2nd Asian Forum on SR, Korea, 1995, pp 91-98.

[3] G.K. Sahoo, Deepa Angal-Kalinin, D.D. Bhawalkar, A.A. Fakhari. A.D. Ghodke et al "Commissioning of the Indus-1 storage ring" proceedings of 7th EPAC-2000, Vienna, 26-30, June 2000, pp 687-689.

[4] K J S Sawhney et al, Synchrotron radiation based beam diagnostics on CAT-TGM beamline, July 2000.